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Waterways Experiment
Station

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An Analysis of Freshwater Mussels (Unionidae) in the Quiver River and Bogue Phalia, Mississippi, 1994-95

by Andrew C. Miller, Barry S. Payne

1. The purpose of this report is to provide a detailed analysis of the freshwater mussel population in the Quiver River and Bogue Phalia, Mississippi, for the years 1994 and 1995. The report includes a description of the study area, the methods used for data collection, and the results of the analysis. The data shows a significant decline in the mussel population over the two-year period, which may be due to a variety of factors including habitat degradation, pollution, and overharvesting. The report also discusses the potential impacts of these findings on the local ecosystem and provides recommendations for future research and management actions.

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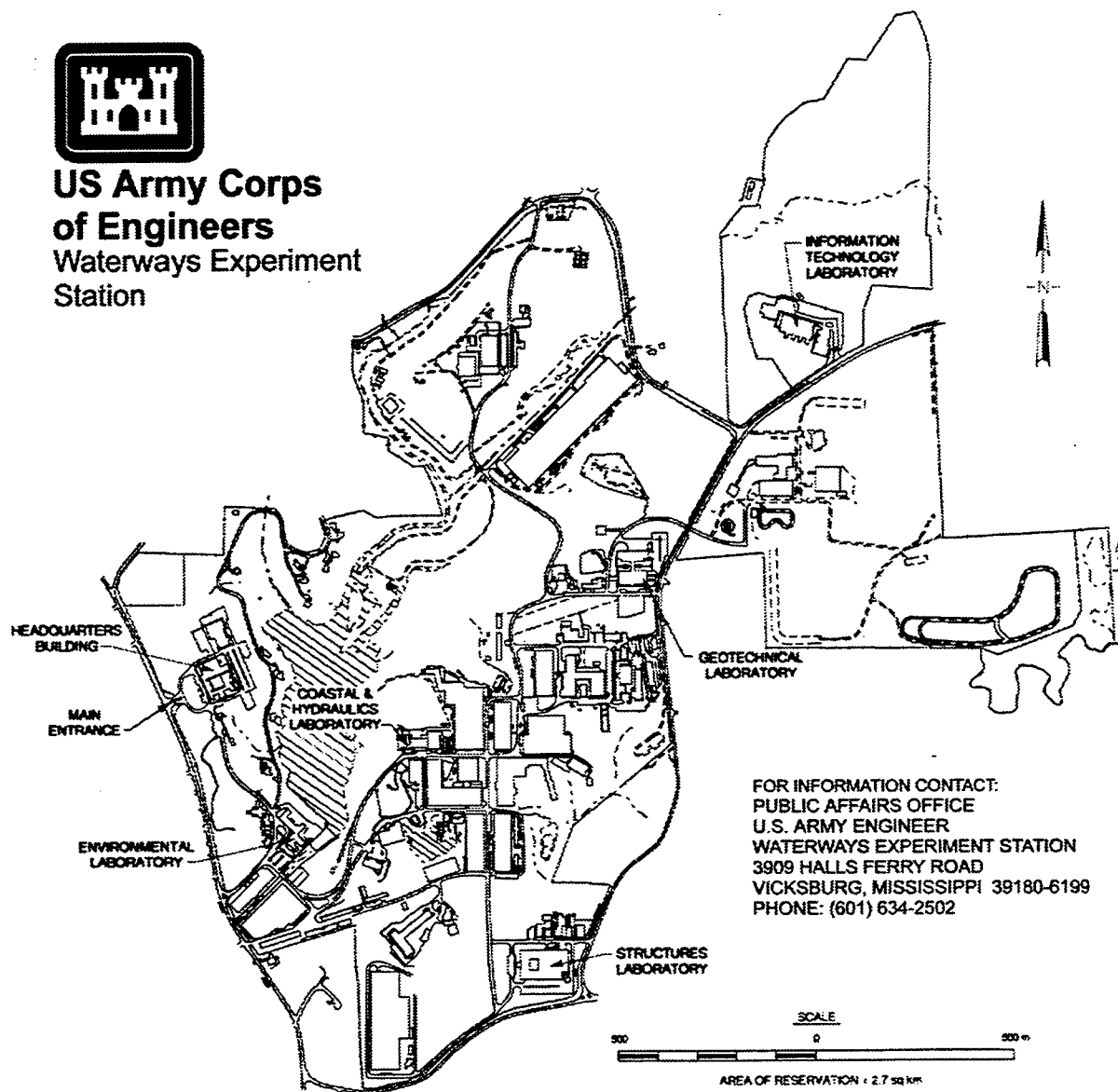
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Final report

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Contents

Preface	v
Conversion Factors, Non-SI Units of Measure	vi
1—Introduction	1
Background	1
Purpose and Scope	2
2—Study Area and Methods	3
Study Area	3
Methods	4
3—The Bivalve Community	8
Characteristics of the Mussel Resource	8
Size Demography of Dominant Populations	16
Economic Value of Mussels in the Project Area	17
4—Discussion	21
The Bivalve Community	21
Impacts of Dredging	22
Effects of Commercial Shell Harvest	22
Recommendations	22
References	24
Appendix A: Results of Quantitative and Qualitative Sampling for Freshwater Mussels in the Quiver River, Mississippi, 1995	A1
Appendix B: Results of Qualitative and Quantitative Sampling for Freshwater Mussels in Bogue Phalia, Mississippi, 1995	B1
SF 298	

List of Tables

Table 1.	Sites Surveyed on the Quiver River and Bogue Phalia, Yazoo Basin Project, 1994-95	5
Table 2.	Freshwater Bivalves Collected Using Qualitative and Quantitative Methods in Bogue Phalia and Quiver River, 1994-95	9
Table 3.	Percent Species Abundance for Freshwater Bivalves Using Qualitative Methods at 26 Locations at the Quiver River, Mississippi, 8 August 1995	10
Table 4.	Percent Abundance of Freshwater Mussels at All Sites on the Quiver River Mile Sampled Using Quantitative Methods, August 1995	11
Table 5.	Frequency of Occurrence of Freshwater Mussels at All Sites on the Quiver River Sampled Using Qualitative Methods, August 1995	12
Table 6.	Mean Density and Standard Error of the Mean for Mussels Collected at Four Locations in the Quiver River, 1995	13
Table 7.	Percent Species Abundance of Freshwater Bivalves Using Qualitative Methods at 11 Sites on Bogue Phalia, Mississippi, 15 August 1995	14
Table 8.	Quantitative Data on Freshwater Mussels From Three Sites on Bogue Phalia River Mile 41.72, Mississippi, 1995	15
Table 9.	Estimated Commercial Value of Two Species of Freshwater Mussels in the Quiver River and Bogue Phalia, Mississippi, Based Upon Data Collected in 1995	19

Preface

A survey to assess community characteristics, density, population demography of dominant species, and the presence of rare or endangered species of mussels (Family: Unionidae) was conducted in the Quiver River and Bogue Phalia, Mississippi, for the U.S. Army Engineer District, Vicksburg. Results are being used to assess the economic value of mussels and to determine the environmental effects of proposed maintenance dredging. Research was conducted by the U.S. Army Engineer Waterways Experiment Station (WES) in the fall of 1994 and spring and summer 1995.

Divers were Messrs. Larry Neill, Robert T. James, Robert Warden, and Johnny Buchanan from the Tennessee Valley Authority. Assistance in the field was provided by Messrs. David Morrow, David Armistead, and Thomas Usery, all from WES. Mr. Marvin Cannon, U.S. Army Engineer District, Vicksburg, assisted with the design of the survey and provided maps and other background information. Figures and tables were prepared by Ms. Geralline Wilkerson, Jackson State University, Jackson, MS.

During the conduct of this study Dr. John W. Keeley was Director, Environmental Laboratory (EL), WES; Dr. Conrad J. Kirby was Chief, Ecological Research Division, EL; and Dr. Alfred F. Cofrancesco, Jr., was Chief, Aquatic Ecology Branch (AEB), EL. Authors of this report were Drs. Andrew C. Miller and Barry S. Payne, AEB.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin.

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Conversion Factors, Non-SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
feet	0.3048	meters
miles (U.S. nautical)	1.852	kilometers
pounds (mass)	0.4535924	kilograms

1 Introduction

Background

The U.S. Army Engineer District, Vicksburg, is considering channel modification in reaches of the Quiver River and Bogue Phalia, tributaries to the Big Sunflower River in west-central Mississippi. Channel alteration would be accomplished by selective dredging. District personnel need to determine if flood conveyance is economically feasible and environmentally sustainable.

Environmental studies are required in part because results of past surveys (Miller, Payne, and Hartfield 1992; Miller and Payne 1995) indicated that valuable stocks of freshwater mussels (Family: Unionidae) inhabit selected reaches of the nearby Big Sunflower River. District personnel and others considered it very likely that mussel stocks are in reaches of Bogue Phalia and Quiver River that could be affected by dredging.

Before the use of plastics, freshwater mussel shells were collected and used to manufacture pearl buttons (Coker 1919). Today, shells are used to culture pearls. Shells are cut into cubes, ground into spheres, and inserted into an oyster. The increased demand during the past 3 to 5 years has pushed the price of shells to about \$6 per pound on the Japanese market (Williams et al. 1992). The preferred shell for pearl making is thick, white, and free of blemishes. Because they are usually abundant and have thick shells, the threeridge (*Amblema p. plicata*) and washboard (*Megaloniaias nervosa*) are in high demand by the industry. In 1991, the total tonnage of shells exported to Japan was 9,000 short tons, but demand has declined in the last 2 years and leveled to about 4,500 short tons (Baker, as cited by Williams et al. 1993). Recent concern over the spread of the exotic zebra mussel (*Dreissena polymorpha*) and its effects on native mussels could increase the demand and price for high-quality shell.

Freshwater mussels in Mississippi tend to be scattered and not found in discrete beds. Mussels are found in pools or runs stabilized by woody debris or aquatic macrophytes. Often they are locally abundant immediately upriver or downriver of a low-water dam or weir. Most surveys in Mississippi have been qualitative, with investigators collecting live mussels or shells by hand. Qualitative data on Mississippi bivalves have been obtained by Hinkley

(1906), Frierson (1911), Isom and Yokley (1968), Grantham (1969), Stern (1976), Yokley (1979), Cooper and Johnson (1980), Hartfield and Rummel (1985), Hartfield and Ebert (1986), and Bogan, Hartfield, and Bogan (1987). In 1993, personnel of the U.S. Army Engineer Waterways Experiment Station (WES) surveyed the majority of the Big Sunflower River for mussels (Miller, Payne, and Hartfield 1992; Miller and Payne 1995). They found four distinctive beds with moderate- to high-density populations (Miller and Payne 1995). However, low-density populations of commercial shells were found along virtually the entire river.

There are no published records on mussels from the Quiver River or Bogue Phalia. Grantham (1969) recorded 13 species of mussels from the Yazoo Basin with only 2 (*Potamilus purpuratus* and *Amblema plicata plicata*) confirmed as occurring in the Big Sunflower River drainage.

Purpose and Scope

The purpose of this report is to present information on the location, species composition, density, and economic value of mussels in selected reaches of the Quiver River and Bogue Phalia, Mississippi. Information will be used by personnel of the Vicksburg District to evaluate the impacts of channel maintenance.

2 Study Area and Methods

Study Area

The study area includes a reach of Bogue Phalia and the Quiver River, two tributaries of the Big Sunflower River (Figure 1). Both are located in the Delta in the northwestern section of Mississippi. Both rivers are low gradient, and substratum consists of sand and silt with little or no gravel. Neither of these rivers has pool-riffle sequences that are characteristic of rivers in high-gradient terrain. Banks are often steep, poorly vegetated, and subject to erosion during high water. There are no aquatic plants in the river, although in some reaches there is considerable woody debris. Water velocity in the summer is usually less than 0.5 ft/sec,¹ although during high discharge velocities greater than 2 ft/sec are common.

The study area in the Quiver River includes a reach between its confluence with the Big Sunflower River, immediately north of Highway 82 in Sunflower County, to the Leflore-Tallahatchie county line. In the Bogue Phalia, the study area includes a reach between Highway 82 and Rosedale, west-central Bolivar County.

Sediments throughout the study area consist mainly of fine-grained sands and silt. In a typical sediment sample, 95-100 percent of the material is less than 0.65 mm. Partially decaying woody vegetation is usually found in depositional areas instead of sand or gravel. Gravel and sands, if present, are usually found downriver of a weir. Numerous weirs exist in the project area as part of previous flood-control projects. They act as low-water dams and hold water, causing slight deposition of fine-grained sediments. Downstream of the weirs, conditions are slightly erosional and sediments accumulate to a lesser extent.

Mussels were collected using quantitative and qualitative methods at 26 sites in the Quiver River and 11 sites in Bogue Phalia (Table 1). Sites were chosen to reflect the range of conditions in both rivers and include straight reaches, bends, and areas immediately upriver and downriver of weirs.

¹ A table of factors for converting non-SI units of measurement to SI units is presented on page vi.

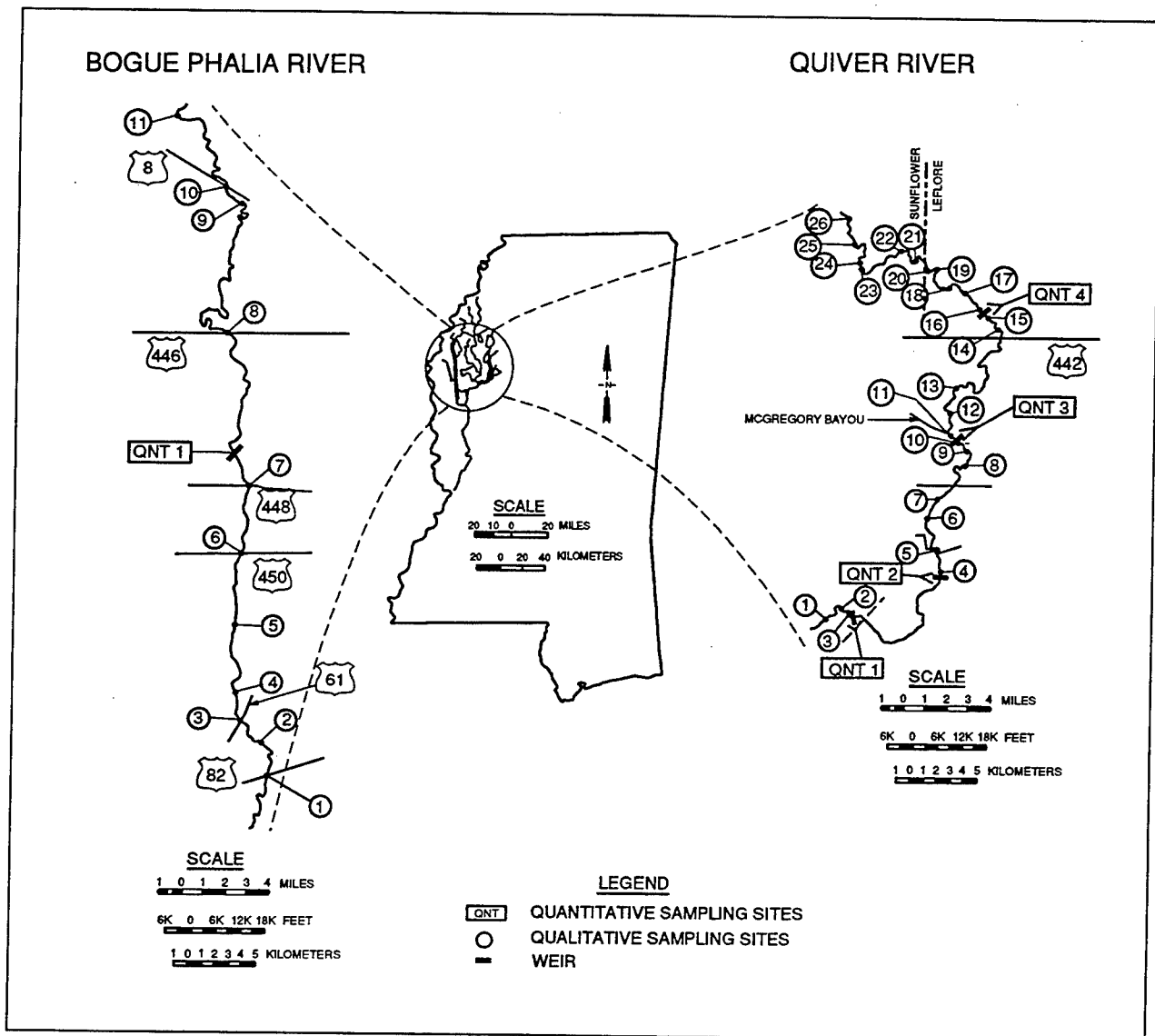


Figure 1. Map of the study areas showing sample locations

Methods

Preliminary reconnaissance

A preliminary reconnaissance of the study area was conducted prior to initiating intensive sampling. This was accomplished by two individuals who traversed the entire project area in a small boat. They stopped frequently and inspected the shore and shallow water for live mussels or dead shells. They also obtained information on substratum conditions, water velocity, and presence of instream cover. Field notes were recorded, and sites that appeared suitable for mussels were marked on topographic maps. Sites likely to support mussels were usually depositional areas immediately upriver of weirs,

Table 1
Sites Surveyed on the Quiver River and Bogue Phalia, Yazoo Basin
Project, 1994-95

Site	RM	Date	Qualitative	Quantitative
Quiver				
1	5.1	Aug 95	X	
2	6.1	Aug 95	X	
3	6.4	Aug 95	X	X
4	12.4	Aug 95	X	X
5	13.2	Aug 95	X	
6	15.0	Aug 95	X	
7	16.1	Aug 95	X	
8	18.0	Aug 95	X	
9	19.4	Aug 95	X	
10	19.7	Aug 95	X	
11	19.9	Aug 95	X	X
12	21.6	Aug 95	X	
13	22.7	Aug 95	X	
14	26.9	Aug 95	X	
15	26.9	Aug 95	X	X
16	27.2	Aug 95	X	
17	27.6	Aug 95	X	
18	28.7	Aug 95	X	
19	31.2	Aug 95	X	
20	31.6	Aug 95	X	
21	32.0	Jun 95	X	
22	33.5	Jun 95	X	
23	34.4	Jun 95	X	
24	34.6	Jun 95	X	
25	35.4	Jun 95	X	
26	36.5	Jun 95	X	
Bogue Phalia				
1	23.7	Aug 95	X	
2	25.6	Aug 95	X	
3	27.4	Aug 95	X	
4	28.2	Aug 95	X	
5	32.2	Aug 95	X	
6	35.8	Aug 95	X	
7	39.8	Aug 95	X	
8	47.8	Aug 95	X	
9	59.5	Aug 95	X	
10	60.8	Aug 95	X	
11	66.9	Aug 95	X	

natural constrictions, or sharp bends. Some reaches immediately downriver of weirs were also chosen for detailed study. In addition to potentially productive sites, others were chosen simply to reflect overall conditions in the project area.

Qualitative and quantitative sampling was accomplished using divers in water deeper than 1 m and by waders in shallow water. Methods used were the same regardless of whether or not divers or waders did the collecting.

Qualitative mussel samples

Qualitative samples were obtained by having two or three individuals collect at a site simultaneously. Each diver placed a specific number of live mussels in each of four nylon bags; five mussels were placed in one bag and 20 were placed in each of the other three bags. Collections were made without bias toward size or type. Workers attempted to exclude the Asiatic clam, *Corbicula fluminea*. If *C. fluminea* was inadvertently collected, it was later eliminated. The total time spent searching was recorded so that the number of mussels collected per minute could be determined.

All mussels were brought to the surface, counted, and identified. Data were recorded on standard data sheets and returned to the laboratory for analysis and plotting. Shells of voucher specimens for each species were placed in plastic zipper-lock bags and labeled with high rag content paper. Mussels not needed for voucher were returned to the river. Methods for sampling mussels are based on techniques described in Isom and Gooch (1986), Kovalak, Dennis, and Bates (1986), Miller and Payne (1988), and Miller et al. 1993. Mussel identification was based on taxonomic keys and descriptive information in Murray and Leonard (1962), Parmalee (1967), Starrett (1971), and Burch (1975). Taxonomy is consistent with Williams et al. (1992).

Quantitative mussel samples

In addition to qualitative samples, quantitative samples (that included unionids as well as *C. fluminea*) were obtained at selected sites. Quantitative techniques were typically used only where density was high enough (usually at least 10 to 20 individuals/square meter) to provide good estimates of species richness and density. In some cases, quantitative samples were taken to adequately characterize conditions in low-density areas.

Quantitative samples were taken by placing either five or ten 0.25-sq m quadrats approximately 1 m apart. At River Mile (RM) 12.4 in the Quiver River, five quadrats were collected. At RM 6.4, 19.7, and 27.0 in the Quiver River and at RM 41.72 in Bogue Phalia, 10 quadrat samples were taken at each site. All sand, gravel, shells, and live bivalves to a depth of 10-15 cm were excavated. Material was placed in a bucket and transported to shore.

Sediment was washed through a series of three screens. All live mussels (including *C. fluminea*) removed from samples were placed in 4- ℓ zipper-lock bags. Each bivalve was then identified and total shell length (SL) measured to the nearest 0.1 mm with digital calipers. Mussels identified and measured in the field were returned to the river unharmed.

Data analysis

Species diversity was determined with the following formula:

$$H' = - \sum p_j \log p_j$$

where p_j is the proportion of the population that is of the j^{th} species (Shannon and Weaver 1949). Evenness was calculated with the modified Hill's ratio (Ludwig and Reynolds 1988). All calculations were done with programs written in BASIC or SAS (Statistical Analytical System) on a personal computer. Discussion of statistical procedures that were used can be found in Green (1979) and Hurlbert (1984). Species area curves and dominance-diversity curves were constructed from qualitative and quantitative biological data.

3 The Bivalve Community

Characteristics of the Mussel Resource

Quiver River

A total of 22 species of native freshwater mussels were collected in the Quiver River, 19 using qualitative methods and 18 using quantitative methods (Table 2). Twenty-six sites were sampled using qualitative methods, and a total of 2,238 mussels were collected (Appendix A, Table A1). The dominant mussel was *Amblema p. plicata*, which comprised over 67 percent of the fauna (Table 3). *Plectomerus dombeyanus* comprised 20 percent of the mussels. The remaining 17 species accounted for less than 15 percent of the assemblage.

Seven hundred and twelve minutes were spent searching for mussels at the 26 sites (Table 3; Table A1, Appendix A). Collecting rate ranged from a low of 0.13 individuals/minute to a high of 6.25 individuals/minute; the overall mean was 3.14/minute.

Quantitative samples were collected at four locations (Table 1), RMs 6.4, 12.4, 19.7, and 27.0 (Tables 4 and 5). Two hundred and thirty 0.25-m² quadrats were taken at the four locations. Overall, the species diversity (0.67 to 0.90) was low, mainly because of the dominance of the threeridge, *Amblema p. plicata*. This species comprised 76 percent of the collection and was found in nearly 50 percent of all samples. Evidence of recent recruitment was low; only at RM 27.0 were individuals collected with a total SL less than 30 mm. Approximately 7 percent of the species and 0.15 percent of the individuals collected were less than 30 mm total SL (Table 4).

There was a tremendous range in total mean mussel density in the Quiver River (Table 6). At RM 6.4, the total density in three samples was less than 1 individual/square meter. At RM 19.7, mean density ranged from 4 to 276.8 individuals/square meter, and overall density was 92.3 individuals/square meter.

Table 2
Freshwater Bivalves Collected Using Qualitative and Quantitative
Methods in Bogue Phalia and Quiver River, 1994-95

Species	Bogue Phalia	Quiver River	
	Qual	Qual	Quant
<i>Arcidens confragosus</i> (Say)		X	X
<i>Anodonta suborbiculata</i> Say		X	
<i>Amblema p. plicata</i> (Say)	X	X	X
<i>Ellipsaria lineolata</i> (Rafinesque)			X
<i>Glebula rotundata</i> (Lamarck)		X	X
<i>Elliptio crassidens</i> (Lamarck)			X
<i>Fusconaia flava</i> (Rafinesque)		X	X
<i>Lampsilis teres</i> (Rafinesque)	X	X	X
<i>Ligumia subrostrata</i> (Say)	X		
<i>Leptodea fragilis</i> (Rafinesque)	X	X	X
<i>Lasmigonia c. complanata</i> (Barnes)		X	
<i>Megalanaia nervosa</i> (Rafinesque)		X	X
<i>Obliquaria reflexa</i> (Rafinesque)		X	X
<i>Plectomerus dombeyanus</i> (Valenciennes)	X	X	X
<i>Pleurobema pyramidatum</i> (I. Lea)		X	
<i>Potamilus pupuratus</i> (Lamarck)	X	X	X
<i>Pyganodon grandis</i> (Say)	X	X	X
<i>Quadrula p. pustulosa</i> (I. Lea)		X	X
<i>Quadrula quadrula</i> (Rafinesque)	X	X	X
<i>Quadrula nodulata</i> (Rafinesque)	X	X	
<i>Tritogonia verrucosa</i> (Rafinesque)		X	X
<i>Truncilla truncata</i> Rafinesque			X
<i>Unio merus declivus</i> (Say)			X
<i>Unio merus tetralasmus</i> (Say)		X	
<i>Utterbackia imbecillis</i> Say	X		
Total species	10	19	18
Total individuals		2,238	2,260

Table 3
Percent Species Abundance for
Freshwater Bivalves Using Quali-
tative Methods at 26 Locations at
the Quiver River, Mississippi,
8 August 1995 (Summary for all
sites)

Species	Total for All Sites
<i>A. p. plicata</i>	67.34
<i>P. dombeyanus</i>	20.29
<i>Q. quadrula</i>	2.28
<i>M. nervosa</i>	2.14
<i>G. rotunda</i>	1.88
<i>P. purpuratus</i>	1.56
<i>Q. p. pustulosa</i>	0.94
<i>C. pyramidatum</i>	0.85
<i>F. flava</i>	0.80
<i>L. fragilis</i>	0.54
<i>A. confragosus</i>	0.36
<i>Q. nodulata</i>	0.27
<i>P. grandis</i>	0.22
<i>O. reflexa</i>	0.18
<i>L. complanata</i>	0.09
<i>U. tetralasmus</i>	0.09
<i>L. teres</i>	0.09
<i>T. verrucosa</i>	0.04
<i>A. suborbiculata</i>	0.04
Total individuals	2,238
Total species	19
Total search time	712
Mussels/minute	3.14

of the collection. The other three species (*Q. quadrula*, *P. purpuratus*, and *A. confragosus*) each comprised 10 percent of the fauna.

Bogue Phalia

Qualitative collections for mussels were made at 11 sites on Bogue Phalia (Table 1). In comparison with the Quiver River, this river exhibited low density and low species richness. A total of 215 mussels were collected using qualitative methods in 220 min (Table 7 and also Appendix B). As with the Quiver River, the fauna was dominated by *A. p. plicata*, which comprised 78 percent of the collection. *Plectomerus dombeyanus* comprised nearly 11 percent of the fauna, and the remaining eight species were each less than 3 percent of the collection. In addition to the thick-shelled species (*A. p. plicata* and *P. dombeyanus*), thin-shelled species such as *Pyganodon grandis*, *Leptodea fragilis*, and *Utterbackia imbecillis*, typically found in fine-grained substratum, were collected.

Quantitative samples were collected at RM 41.72 on Bogue Phalia in October 1995 (Table 8). At the four sites, total mean density ranged from 0.0 to 3.2 individuals/square meter; the overall mean was 1.33 individuals/square meter. The fauna was dominated by *A. p. plicata*, which comprised 70 percent

Table 4
Percent Abundance of Freshwater Mussels at All Sites on the
Quiver River Mile Sampled Using Quantitative Methods, August
1995

Species	RM 6.4	RM 12.4	RM 19.7	RM 27.0	Total
<i>A. p. plicata</i>	81.48	71.71	77.02	74.19	76.11
<i>P. dombeyanus</i>	8.33	13.82	20.30	17.53	18.54
<i>M. nervosa</i>	0.93	3.95	1.16	1.62	1.46
<i>Q. pustulosa</i>	0.93	7.24	0.29	0.81	0.93
<i>F. flava</i>	0.00	0.00	0.07	2.44	0.71
<i>Q. quadrula</i>	0.00	0.00	0.36	1.14	0.53
<i>P. purpuratus</i>	0.00	0.66	0.29	0.81	0.44
<i>L. fragilis</i>	0.93	0.66	0.22	0.49	0.35
<i>P. pyramidatum</i>	4.63	0.00	0.00	0.00	0.22
<i>P. grandis</i>	0.93	1.32	0.00	0.00	0.13
<i>T. truncata</i>	0.93	0.00	0.00	0.16	0.09
<i>E. lineolata</i>	0.00	0.00	0.00	0.16	0.04
<i>A. confragosus</i>	0.93	0.00	0.00	0.00	0.04
<i>G. rotundata</i>	0.00	0.66	0.00	0.00	0.04
<i>O. reflexa</i>	0.00	0.00	0.22	0.16	0.18
<i>E. crassidens</i>	0.00	0.00	0.00	0.16	0.04
<i>L. teres</i>	0.00	0.00	0.00	0.16	0.04
<i>T. verrucosa</i>	0.00	0.00	0.07	0.00	0.04
<i>U. declivus</i>	0.00	0.00	0.00	0.16	0.04
Total individuals	108	152	1,384	616	2,260
Total species	9	8	10	14	19
Menhinik's Index	0.87	0.65	0.27	0.56	
Diversity	0.78	0.98	0.67	0.90	
Evenness	0.42	0.51	0.61	0.49	
% Individuals < 30 mm	0.00	0.00	0.00	0.16	
% Species < 30 mm	0.00	0.00	0.00	7.14	

Table 5 Frequency of Occurrence of Freshwater Mussels at All Sites on the Quiver River Sampled Using Qualitative Methods, August 1995					
Species	RM 6.4	RM 12.4	RM 19.7	RM 27.0	Total
<i>A. p. plicata</i>	14.00	40.00	68.33	60.00	46.96
<i>P. dombeyanus</i>	10.00	25.00	60.00	33.33	33.04
<i>M. nervosa</i>	2.00	5.00	20.00	13.33	10.43
<i>Q. pustulosa</i>	2.00	16.67	3.33	5.00	6.96
<i>P. purpuratus</i>	0.00	1.67	6.67	8.33	4.35
<i>F. flava</i>	0.00	0.00	1.67	13.33	3.91
<i>Q. quadrula</i>	0.00	0.00	6.67	8.33	3.91
<i>L. fragilis</i>	2.00	1.67	5.00	5.00	3.48
<i>P. grandis</i>	2.00	3.33	0.00	0.00	1.30
<i>O. reflexa</i>	0.00	0.00	3.33	1.67	1.30
<i>T. truncata</i>	2.00	0.00	0.00	1.67	0.87
<i>P. pyramidatum</i>	2.00	0.00	0.00	0.00	0.43
<i>E. crassidens</i>	0.00	0.00	0.00	1.67	0.43
<i>L. teres</i>	0.00	0.00	0.00	1.67	0.43
<i>G. rotundata</i>	0.00	1.67	0.00	0.00	0.43
<i>A. confragosus</i>	2.00	0.00	0.00	0.00	0.43
<i>E. lineolata</i>	0.00	0.00	0.00	1.67	0.43
<i>T. verrucosa</i>	0.00	0.00	1.67	0.00	0.43
<i>U. declivus</i>	0.00	0.00	0.00	1.67	0.43
Total sites	5	12	6	6	29
Total quadrats	50	60	60	60	230

Location of valuable mussel resources in the project area

As illustrated in Table 6, high-density populations of mussels in the Quiver River were found at RMs 27.0 and 19.7. Although the river was thoroughly surveyed and 26 sites were critically examined, there is always the possibility that other beds could be found. Regardless, in comparison with other rivers, both the Quiver River and Bogue Phalia have relatively uniform conditions of habitat throughout. With the exception of weirs, most areas had low flow, fine-grained substratum, and fairly steep banks. Mussel habitat was relatively similar throughout both rivers. Although high-density areas exist, it is accurate to state that much of the shallow areas along the shore of both rivers provided fair to good mussel habitat.

Table 6 Mean Density and Standard Error of the Mean for Mussels Collected at Four Locations in the Quiver River, 1995													
River Mile	Site Numbers												
	1	2	3	4	5	6	7	8	9	10	11	12	Overall Mean
Mean Values													
6.4	42.8	0.4	0.0	0.0									8.6
12.4	1.6	9.6	6.4	6.4	0.8	0.0	12.0	6.4	5.6	0.0	16.0	58.8	10.1
19.7	24.8	276.8	47.6	46.8	153.6	4.0							92.3
27.0	112.4	57.6	0.4	4.8	62.8	8.4							41.1
River Mile	Site Numbers												
	1	2	3	4	5	6	7	8	9	10	11	12	Overall Value
Standard Error of the Mean													
6.4	17.5	0.4	0.0	0.0	0.0								4.2
12.4	1.1	2.1	1.7	2.5	0.6	0.0	3.9	2.1	3.3	0.0	3.2	6.2	2.2
19.7	12.5	27.8	23.3	20.0	43.8	1.6							15.8
27.0	21.7	13.6	0.4	1.6	9.0	2.6							6.8
Note: Five quadrats were collected at each site at RM 12.4; ten quadrats were taken at each of the other three river miles.													

Table 7
Percent Species Abundance of Freshwater Bivalves Using Qualitative Methods at 11 Sites on Bogue Phalia, Mississippi,
15 August 1995

Species	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Total
	RM 33.7	RM 25.6	RM 27.4	RM 28.2	RM 32.2	RM 35.8	RM 39.8	RM 47.5	RM 59.5	RM 60.8	RM 66.9	
<i>A. p. plicata</i>	33.33	22.22	0.00	81.63	40.00	0.00	0.00	76.48	90.01	85.30	91.07	78.14
<i>P. dombeyanus</i>	33.33	66.66	0.00	14.29	0.00	0.00	0.00	0.00	0.00	0.00	3.57	10.70
<i>P. grandis</i>	16.67	0.00	0.00	0.00	0.00	0.00	0.00	11.76	0.00	8.82	0.00	2.79
<i>Q. quadrula</i>	0.00	5.56	0.00	0.00	20.00	0.00	0.00	5.88	0.00	0.00	3.57	2.33
<i>P. purpuratus</i>	0.00	5.56	0.00	2.04	20.00	0.00	0.00	5.88	0.00	0.00	0.00	1.86
<i>L. fragilis</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.33	0.00	1.79	0.93
<i>L. teres</i>	0.00	0.00	0.00	2.04	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.93
<i>L. subrostrata</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.88	0.00	0.93
<i>Q. nodulata</i>	16.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.33	0.00	0.00	0.93
<i>U. imbecillis</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.33	0.00	0.00	0.46
Total individuals	6	18	0	49	5	0	0	17	30	34	56	215
Total species	4	4	0	4	4	0	0	4	4	3	4	10
Total collection time, min	20	20	20	20	20	20	20	20	20	20	20	220
Mussels/min	0.30	0.90	0.00	2.45	0.25	0.00	0.00	0.85	1.50	1.70	2.80	0.98

Table 8 Quantitative Data on Freshwater Mussels From Three Sites on Bogue Phalia River Mile 4.1.72, Mississippi, 1995									
Species	Site 1, LDB ¹		Site 2, Channel		Site 3, RDB ²		Total		Frequency
	Abundance	Frequency	Abundance	Frequency	Abundance	Frequency	Abundance	Frequency	
<i>A. p. plicata</i>	0.00	0.00	75.00	20.00	50.00	10.00	70.00	10.00	10.00
<i>Q. quadrula</i>	0.00	0.00	12.50	10.00	0.00	0.00	10.00	3.33	3.33
<i>P. purpuratus</i>	0.00	0.00	0.00	0.00	50.00	10.00	10.00	3.33	3.33
<i>A. confragosus</i>	0.00	0.00	12.50	10.00	0.00	0.00	10.00	3.33	3.33
Total individuals	0		8		2		10		
Total quadrat samples	10		10		10		30		
Mean density		0.0		3.2		0.8	1.33		
% individual < 30 mm							0.00		
% species < 30 mm							0.00		
Menhinik's Index							1.26		
Species diversity (H')							0.94		
Equitability							0.73		
Note: Sites were immediately upriver of a weir at Station 6. There was no water downriver of the weir. ¹ Left-descending bank. ² Right-descending bank.									

Size Demography of Dominant Populations

Only mussels from the quantitative samples in the Quiver River were used for demographic analysis. The size demography of these species was similar at all locations; therefore individuals from all sites were grouped for analysis (Figure 2). Only populations with at least 15 individuals were analyzed.

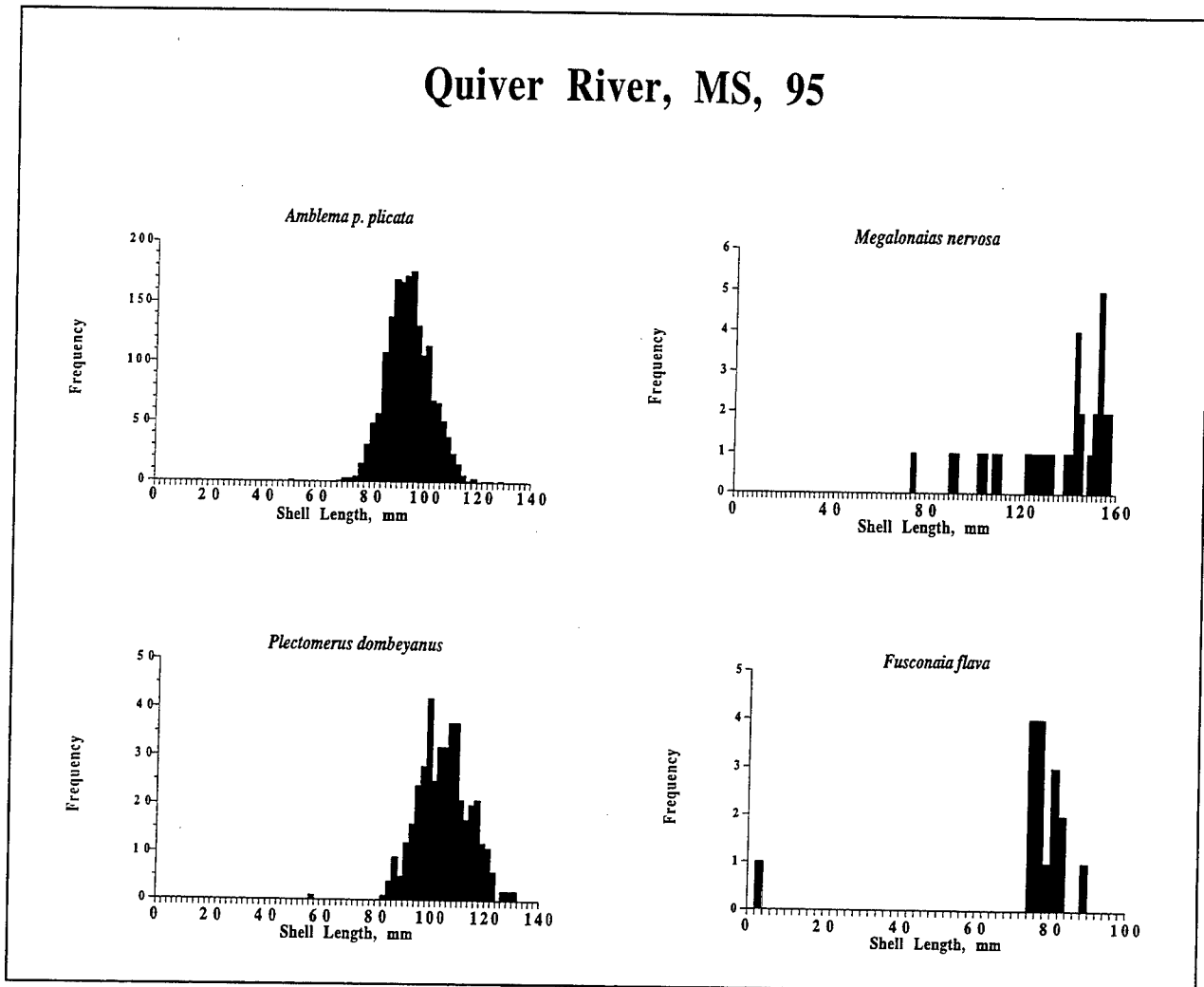


Figure 2. Size demography of dominant mussels in the Quiver River, 1995

Ambblema plicata plicata

With the exception of one mussel 51.5 mm long, *A. p. plicata* individuals ranged from 69.2 to 129.5 mm total SL (Figure 2). This population clearly consists of several closely spaced cohorts, although overlap obscured age class separations. The modal length of this population ranged from 90 to 98 mm.

Evidence of recent recruitment for this species, as with all mussels listed in Table 4, was extremely poor.

Megaloniaias nervosa

Mean SL of *M. nervosa* population ranged from 74.7 to 88.7 mm. This was a medium- to older aged population with no evidence of recent recruitment. Clearly several age classes were present, although since few individuals were collected, it is difficult to discern cohorts.

Plectomerus dombeyanus

With the exception of one individual less than 80 mm long, total SL of *P. dombeyanus* ranged between 83.4 and 131.7 mm. As with the other two thick-shelled species, several cohorts are present although not easily discerned from these data.

Fusconaia flava

A single individual of *F. flava* was less than 4 mm long; the remainder of the population was between 74.4 and 88.7 mm total SL. It is likely that at least three cohorts of *F. ebena* were present, one represented by the single small individual, one less than 80 mm total SL, and one greater than 80 mm total SL.

Economic Value of Mussels in the Project Area

Background

The commercial shell industry typically purchases only thick-shelled species to make inserts for oysters to culture pearls. In addition to having a thick shell, shell nacre should be white and free of blemishes. Although many species are potentially marketable (i.e., *Quadrula* spp., *Fusconaia* spp., and *Pleurobema* spp.), usually the threeridge (*A. p. plicata*) and washboard (*M. nervosa*) comprise the majority of the market. In the Big Sunflower River, these two species will certainly dominate commercial sales. The bank climber (*Plectomerus dombeyanus*) is abundant although not marketable.

Size limits for freshwater mussels are based on minimum shell height. If a live specimen cannot pass through a metal ring of a given diameter, then it is considered legal. In scientific surveys, total SL is usually measured and used to determine length-weight or length-age relationships. In this survey, SL of each specimen collected using quantitative methods was measured. Shell height measures were calculated from length-height relationships obtained from specimens collected in the Big Sunflower River (Miller and Payne 1995).

Estimate of the commercial value of mussels in the project area

In February 1994, the Mississippi Department of Wildlife, Fisheries and Parks tentatively established minimum sizes for marketable shells in the Big Sunflower River. The minimum marketable size of *A. p. plicata* was set at 2 5/8 (66.7 mm) in. high. The minimum size of *M. nervosa* (washboard) was set at 3.25 in. (82.6 mm) high for the first year of commercial harvest and 4.0 in. high (101.6 mm) for 1995 and beyond. There is an obvious short-term advantage for harvesters to have shell sizes set small. However, a small-sized shell will be less marketable than larger shells. The larger shells potentially provide more inserts for pearl production than smaller ones.

Shell height (SH) to SL ratios for these two marketable species, based upon data collected in the Sunflower River (Miller and Payne 1995), are as follows:

$$A. p. plicata \text{ SL} = 0.57 * \text{SH} + 12.46 \text{ (r} = 0.86\text{)}$$

$$M. nervosa \text{ SL} = 0.65 * \text{SL} + 6.57 \text{ (r} = 0.95\text{)}$$

Based on these relationships, all *A. p. plicata* greater than 95 mm (3.7 in.) long, and all *M. nervosa* greater than 146 mm long (5.7 in.) are marketable.

Maximum and Minimum Shell Lengths of Two Species of Marketable Mussels, Quiver River, 1995		
Parameter	<i>A. p. plicata</i>	<i>M. nervosa</i>
Total Number Analyzed	1,720	33
Minimum SL	51.55	74.71
Maximum SL	129.51	156.78
Range	77.96	82.07
Minimum Marketable SL	95	116.9
% of the population > minimum marketable SL	41.69	78.79

Average total organism wet weight was estimated based on these sizes. Approximately 42 percent of all *A. p. plicata* were greater than 66.67 mm SH and potentially marketable. Average mass of all *A. p. plicata* greater than 66.67 mm high (SL = 95 mm) was 168.07 g. The percent marketable *M. nervosa* was estimated at 78.79 percent, and the average mass of this species greater than 82.55 mm high (SL = 116.9 mm) was 438.81 g. Based upon information provided by the Mississippi Department of Wildlife, Fisheries and Parks, the price per pound (total live weight) was estimated to be \$1.00.

The number of river miles to be affected by dredging in the Quiver River and Bogue Phalia are 56 and 43, respectively (Table 9). Based on the assumption on the amount of available shoreline habitat (4 m in the

Table 9
Estimated Commercial Value of Two Species of Freshwater Mus-
sels in the Quiver River and Bogue Phalia, Mississippi, Based Upon
Data Collected in 1995 (Values Rounded to Whole Numbers)

Parameter	Quiver River	Bogue Phalia
River miles	56	43
Length, m	90,104	69,509
Width of channel available for mussels, m	4	2
Total area, sq m	360,416	139,018
Available, habitat, %	0.5	0.25
Available area	180,208	34,754
Mean mussel density	39.3	1.3
% Abundance		
<i>A. p. plicata</i>	76.1	78.1
<i>M. nervosa</i>	1.5	0.0
Density, Number/sq m		
<i>A. p. plicata</i>	29.9	1.0
<i>M. nervosa</i>	0.6	0.0
Total Number Present		
<i>A. p. plicata</i>	5,390,243	36,119
<i>M. nervosa</i>	103,400	0
% Marketable		
<i>A. p. plicata</i>	41.7	41.7
<i>M. nervosa</i>	78.8	1.0
Number of Marketable Individuals Present		
<i>A. p. plicata</i>	2,247,192	15,058
<i>M. nervosa</i>	81,469	0
Mean wet weight, g		
<i>A. p. plicata</i>	168.1	168.1
<i>M. nervosa</i>	438.8	438.8
Total Mass Present, lb		
<i>A. p. plicata</i>	830,991.4	5,568.3
<i>M. nervosa</i>	78,656.2	0.0
Price/lb	\$1.00	\$1.00
Total value		
<i>A. p. plicata</i>	\$830,991	\$5,568
<i>M. nervosa</i>	\$78,656	\$0
Total in river	\$909,648	\$5,568
Grand total	\$915,216	

Quiver River and 2 m in Bogue Phalia), an estimate of the total possible mussel habitat was made. It was assumed that 50 percent of the Quiver River and 25 percent of the Bogue Phalia was suitable for mussels; therefore, approximately 180,000 and 35,000 sq m of mussel habitat could be affected by dredging. Although the dredge typically only works in the center of the river, both of these streams are so narrow that it was assumed that dredging in the channel would affect all mussel habitat.

An estimate of the total number of *A. p. plicata* and *M. nervosa* in the affected reaches was made, and this value was converted to total biomass in pounds. If mussels sell at \$1 per pound from the project area, the total value would be approximately \$910,000 in the Quiver River and \$5,000 in Bogue Phalia for a grand total of \$915,000 (Table 9). These estimates are based on population structure and density determined in the fall of 1995. Recent recruits will become marketable each year, and they will have commercial value.

4 Discussion

The Bivalve Community

Certain sections of the Quiver River are characterized by high density and often extreme dominance by a single species (*A. p. plicata*). However, in most reaches mussels are scattered and densities are less than 5/m². Mussel densities were also low in Bogue Phalia, mainly because of reduced water levels. During the summer, many reaches have extremely shallow water (several inches deep), with little or no flow. Such conditions will be extremely stressful for mussels. There was little or no evidence of recent recruitment in either river. Lack of small specimens was noted in high-density as well as low-density areas; it is unlikely that high-density populations inhibit recruitment.

It is difficult to determine why mussels reach extremely high densities in the river, yet exhibit so little evidence of recent recruitment. In comparison with northern habitats in northern latitudes, these mussels could be stressed by elevated temperatures in the summer, low-calcium-content water, and high-sediment deposits. Although these effects are obviously negative, they do not appear to have affected the ability of these areas to support high-density populations.

In comparison with the Sunflower River, which is within the same drainage, these two rivers support fewer individuals and species. A total of 26 species of native mussels were collected in the Sunflower River, as compared with 22 in the Quiver and 10 in Bogue Phalia. It is difficult to make meaningful density comparisons among rivers, although clearly high-density sites exist in both the Big Sunflower and Quiver rivers. At a site at RM 19.7 in the Quiver River, total density was estimated at 276 individuals/square meter. Immediately downriver of abandoned Lock and Dam 1 in the Big Sunflower River, mean density of 10 quadrats was 235 individuals/square meter.

The total value of *A. p. plicata* and *M. nervosa* in the Big Sunflower River was estimated at \$2.7 million dollars for 1994 (Miller and Payne 1995). This estimate included four mussel beds as well as nearly 50 river miles. Although total miles in Bogue Phalia and Quiver River were slightly greater, the density and amount of habitat were less than in the Sunflower River. It was estimated

that the commercial value of *A. p. plicata* and *M. nervosa* in the project area was approximately \$915,216 in Bogue Phalia and Quiver River.

Impacts of Dredging

Removal of mussels from the river bottom, using either a hydraulic dredge or dragline, and transporting them to an upland disposal site would result in 100-percent mortality. If dredged material is deposited in the water, an unknown percentage of mussels would survive. Most mussels have the ability to extricate themselves after being buried, as long as sediments are not more than a few centimeters deep. However, there is the likelihood that high mortality will result as a result of the dredge. Mussels can be negatively affected by the effects of elevated suspended solids immediately downriver of a dredge. However, the molluscan gill and feeding palps are designed to separate nutritious particles from inorganic particles without food value. In addition, mussels in the project area have adapted to a naturally high suspended sediment regimen. Because of the uncertainty of these estimates, the effects of elevated suspended sediments immediately downriver of the dredge on mussels were not determined.

Effects of Commercial Shell Harvest

A commercial shell harvester using scuba or surface-supplied air has the potential for removing virtually all mussels in a bed. A brail misses many mussels and can be less detrimental to valuable beds. However, an experienced shell diver should take only commercially valuable species. Uncommon or rare species with no commercial value should be left in the river and not dumped on shore. In addition, when size limits are placed on the population, not all specimens will be collected. Commercial shell harvest has the potential to be detrimental to mussel resources. However, if carefully regulated, existing populations could be maintained.

Recommendations

With careful planning, mussels in the Quiver River and Bogue Phalia could survive selective commercial harvest. In addition, some will survive the effects of dredging. In order to protect as many mussels as possible, the following recommendations are made:

- a. The effects of dredging and commercial harvest should be monitored. Quantitative and qualitative methods should be used to collect mussels in the areas where commercial harvesting is permitted and where dredging took place. Information should also be obtained from non-dredged areas. Information on density, community composition,

evidence of recent recruitment, population structure, and shell morphometrics should be obtained. These findings will be used to assist with regulating the commercial harvest and can be used to assess the environmental effects of maintenance dredging.

- b.* Selected areas should be set aside as a sanctuary where no harvesting would be permitted. This would provide an undisturbed community for future reproduction as well as a control area with no commercial impact.

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Appendix A

Results of Quantitative and Qualitative Sampling for Freshwater Mussels in the Quiver River, Mississippi, 1995

Table A1

Percent Species Abundance for Freshwater Bivalves Using Qualitative Methods at 26 Locations at the Quiver River, Mississippi, 8 August 1995

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9
Species	RM 5.1	RM 6.1	RM 6.4	RM 12.4	RM 13.2	RM 15	RM 16.1	RM 18	RM 19.4
<i>A. p. plicata</i>	39.29	80.21	60.70	77.60	4.88	94.19	54.21	66.67	27.59
<i>P. dombeyanus</i>	7.14	11.46	30.85	12.00	60.98	0.00	39.25	18.39	65.52
<i>Q. quadrula</i>	0.00	1.56	2.49	0.00	2.44	0.00	0.00	0.00	0.00
<i>M. nervosa</i>	21.43	1.04	1.00	4.80	0.00	0.00	0.93	4.60	1.15
<i>G. rotunda</i>	0.00	0.00	0.00	2.40	0.00	0.00	0.00	0.00	0.00
<i>P. purpuratus</i>	7.14	0.52	0.50	1.60	12.20	1.16	0.93	5.75	0.00
<i>Q. p. pustulosa</i>	7.14	2.08	1.49	0.00	0.00	0.00	0.93	2.30	1.15
<i>C. pyramidatum</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.30
<i>F. flava</i>	0.00	0.00	0.00	0.00	2.44	2.33	2.80	1.15	2.30
<i>L. fragilis</i>	0.00	0.52	1.99	0.80	4.88	0.00	0.93	0.00	0.00
<i>A. confragosus</i>	7.14	0.52	0.00	0.00	4.88	0.00	0.00	0.00	0.00
<i>Q. nodulata</i>	7.14	1.56	0.50	0.00	0.00	0.00	0.00	0.00	0.00
<i>P. grandis</i>	3.57	0.00	0.00	0.80	4.88	0.00	0.00	0.00	0.00
<i>O. reflexa</i>	0.00	0.52	0.50	0.00	2.44	1.16	0.00	0.00	0.00
<i>L. complanata</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>U. tetralasmus</i>	0.00	0.00	0.00	0.00	0.00	1.16	0.00	0.00	0.00
<i>L. teres</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>T. verrucosa</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.15	0.00
<i>A. suborbiculata</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total individuals	28	192	201	125	41	86	107	87	87
Total species	8	10	9	7	9	5	7	7	6
Total search time	31	42	119	20	20	20	20	20	20
Mussels/min	0.90	4.57	1.69	6.25	2.05	4.30	5.35	4.35	4.35

(Sheet 1 of 3)

Table A1 (Continued)									
Species	Site 10	Site 11	Site 12	Site 13	Site 14	Site 15	Site 16	Site 17	Site 18
	RM 19.7	RM 19.9	RM 21.6	RM 22.7	RM 26.9	RM 26.9	RM 27.2	RM 27.6	RM 28.7
<i>A. p. plicata</i>	89.11	82.73	52.58	73.86	69.86	76.00	76.83	69.49	60.00
<i>P. dombeyanus</i>	10.89	10.91	44.33	21.59	24.66	18.67	10.98	27.12	25.71
<i>Q. quadrula</i>	0.00	0.91	0.00	0.00	0.00	1.33	2.44	1.69	0.00
<i>M. nervosa</i>	0.00	0.00	0.00	0.00	0.00	0.00	4.88	1.69	8.57
<i>G. rotunda</i>	0.00	3.64	2.06	2.27	0.00	0.00	0.00	0.00	0.00
<i>P. purpuratus</i>	0.00	0.00	0.00	0.00	2.74	0.00	1.22	0.00	5.71
<i>Q. p. pustulosa</i>	0.00	1.82	1.03	0.00	0.00	0.00	0.00	0.00	0.00
<i>C. pyramidatum</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>F. flava</i>	0.00	0.00	0.00	1.14	2.74	4.00	0.00	0.00	0.00
<i>L. fragilis</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>A. confragosus</i>	0.00	0.00	0.00	1.14	0.00	0.00	0.00	0.00	0.00
<i>Q. nodulata</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>P. grandis</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>O. reflexa</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>L. complanata</i>	0.00	0.00	0.00	0.00	0.00	0.00	2.44	0.00	0.00
<i>U. tetralasmus</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>L. teres</i>	0.00	0.00	0.00	0.00	0.00	0.00	1.22	0.00	0.00
<i>T. verrucosa</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>A. suborbiculata</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total individuals	101	110	97	88	73	150	82	59	35
Total species	2	5	4	5	4	4	7	4	4
Total search time	20	20	20	20	20	20	20	20	20
Mussels/min	5.05	5.5	4.85	4.4	3.65	7.5	4.1	2.95	1.75
(Sheet 2 of 3)									

Table A1 (Concluded)

Species	Site 19	Site 20	Site 21	Site 22	Site 23	Site 24	Site 25	Site 26	Total for all sites
	RM 31.2	RM 31.6	RM 32	RM 33.5	RM 34.36	RM 34.6	RM 35.4	RM 36.5	
<i>A. p. plicata</i>	91.18	93.33	28.26	40.74	41.30	79.00	56.38	0.00	67.34
<i>P. dombeyanus</i>	3.92	6.67	19.57	11.11	28.26	13.00	3.36	0.00	20.29
<i>Q. quadrula</i>	0.00	0.00	4.35	11.11	0.00	0.00	20.81	0.00	2.28
<i>M. nervosa</i>	1.96	0.00	13.04	14.81	0.00	4.00	1.34	0.00	2.14
<i>G. rotunda</i>	0.00	0.00	30.43	11.11	23.91	0.00	1.34	25.00	1.88
<i>P. purpuratus</i>	2.94	0.00	2.17	3.70	2.17	1.00	2.68	25.00	1.56
<i>Q. p. pustulosa</i>	0.00	0.00	2.17	0.00	0.00	1.00	2.01	0.00	0.94
<i>C. pyramidatum</i>	0.00	0.00	0.00	0.00	0.00	0.00	11.41	0.00	0.85
<i>F. flava</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80
<i>L. fragilis</i>	0.00	0.00	0.00	3.70	0.00	0.00	0.67	25.00	0.54
<i>A. confragosus</i>	0.00	0.00	0.00	0.00	2.17	1.00	0.00	0.00	0.36
<i>Q. nodulata</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27
<i>P. grandis</i>	0.00	0.00	0.00	3.70	0.00	0.00	0.00	0.00	0.22
<i>O. reflexa</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18
<i>L. complanata</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
<i>U. tetralasmus</i>	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.09
<i>L. teres</i>	0.00	0.00	0.00	0.00	2.17	0.00	0.00	0.00	0.09
<i>T. verrucosa</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
<i>A. suborbiculata</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	25.00	0.04
Total individuals	102	15	46	27	46	100	149	4	2,238
Total species	4	2	7	8	6	7	9	4	19
Total search time	20	20	30	30	30	30	30	30	712
Mussels/min	5.1	0.75	1.53	0.90	1.53	3.33	4.97	0.13	3.14
(Sheet 3 of 3)									

Table A2
Percent Abundance of Freshwater Rivers, Based on Quantitative Sampling, at Quiver River Mile 6.4, August 1995

Species	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Total
<i>A. p. plicata</i>	82.24	0.00	0.00	0.00	0.00	81.48
<i>P. dombeyanus</i>	8.41	0.00	0.00	0.00	0.00	8.33
<i>P. pyramidatum</i>	4.67	0.00	0.00	0.00	0.00	4.63
<i>L. fragilis</i>	0.93	0.00	0.00	0.00	0.00	0.93
<i>Q. pustulosa</i>	0.93	0.00	0.00	0.00	0.00	0.93
<i>T. truncata</i>	0.93	0.00	0.00	0.00	0.00	0.93
<i>M. nervosa</i>	0.00	100.00	0.00	0.00	0.00	0.93
<i>P. grandis</i>	0.93	0.00	0.00	0.00	0.00	0.93
<i>A. confragosus</i>	0.93	0.00	0.00	0.00	0.00	0.93
Total individuals	107	1	0	0	0	108
Total species	9	1	0	0	0	9
Menhinik's Index	0.78	-	0	0	0	0.87
Diversity (H')	0.73	-	0	0	0	0.78
Evenness	0.43	-	0	0	0	0.42
% Individuals < 30 mm	0.00	-	0	0	0	0.00
% Species < 30 mm	0.00	-	0	0	0	0.00

Table A3
Frequency of Occurrence of Freshwater Rivers, Based on Quantitative Sampling, at Quiver River Mile 6.4, August 1995

Species	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Total
<i>A. p. plicata</i>	70.00	0.00	0.00	0.00	0.00	14.00
<i>P. dombeyanus</i>	50.00	0.00	0.00	0.00	0.00	10.00
<i>L. fragilis</i>	10.00	0.00	0.00	0.00	0.00	2.00
<i>P. pyramidatum</i>	10.00	0.00	0.00	0.00	0.00	2.00
<i>M. nervosa</i>	0.00	10.00	0.00	0.00	0.00	2.00
<i>T. truncata</i>	10.00	0.00	0.00	0.00	0.00	2.00
<i>Q. quadrula</i>	10.00	0.00	0.00	0.00	0.00	2.00
<i>P. grandis</i>	10.00	0.00	0.00	0.00	0.00	2.00
<i>A. confragosus</i>	10.00	0.00	0.00	0.00	0.00	2.00
Total samples	10	10	10	10	10	50

Table A4 Percent Abundance of Freshwater Rivers, Based on Quantitative Sampling, at Quiver River Mile 12.4, August 1995													
Species	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12	Total
<i>A. p. plicata</i>	50.00	41.67	62.50	50.00	0.00	0.00	80.00	25.00	28.57	0.00	70.00	90.14	71.71
<i>P. dombeyanus</i>	0.00	33.33	37.50	25.00	0.00	0.00	13.33	12.50	57.14	0.00	15.00	2.82	13.82
<i>Q. quadrula</i>	0.00	16.67	0.00	0.00	100.00	0.00	0.00	0.00	14.29	0.00	15.00	5.63	7.24
<i>M. nervosa</i>	50.00	0.00	0.00	0.00	0.00	0.00	0.00	50.00	0.00	0.00	0.00	1.41	3.95
<i>P. grandis</i>	0.00	8.33	0.00	12.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.32
<i>L. fragilis</i>	0.00	0.00	0.00	12.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.66
<i>P. purpuratus</i>	0.00	0.00	0.00	0.00	0.00	0.00	6.67	0.00	0.00	0.00	0.00	0.00	0.66
<i>G. rotundata</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.50	0.00	0.00	0.00	0.00	0.66
Total individuals	2	12	8	8	1	0	15	8	7	0	20	71	152
Total species	2	5	2	4	1	0	3	4	3	0	3	4	8
Menhik's Index	1.40	1.10	0.71	1.41	-	0.00	0.77	1.41	1.13	0.00	0.67	0.47	0.65
Species diversity	0.69	1.24	0.66	1.21	-	0.00	0.63	1.21	0.96	0.00	0.82	0.42	0.98
Evenness	0.00	1.18	1.23	1.27	-	0.00	0.65	1.27	1.25	0.00	0.76	0.51	0.51
% Individuals < 30 mm	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Species < 30 mm	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table A5
Frequency of Occurrence of Freshwater Rivers, Based on Quantitative Sampling, at Quiver River Mile 12.4, August 1995

Species	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12	Total
<i>A. p. plicata</i>	20.00	40.00	60.00	60.00	0.00	0.00	60.00	40.00	20.00	0.00	80.00	100.00	40.00
<i>P. dombeyanus</i>	0.00	60.00	60.00	20.00	0.00	0.00	40.00	20.00	20.00	0.00	40.00	40.00	25.00
<i>Q. quadrula</i>	0.00	40.00	0.00	0.00	20.00	0.00	0.00	0.00	20.00	0.00	60.00	60.00	16.67
<i>M. nervosa</i>	20.00	0.00	0.00	0.00	0.00	0.00	0.00	20.00	0.00	0.00	0.00	20.00	5.00
<i>P. grandis</i>	0.00	20.00	0.00	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.33
<i>L. fragilis</i>	0.00	0.00	0.00	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.67
<i>P. purpuratus</i>	0.00	0.00	0.00	0.00	0.00	0.00	20.00	0.00	0.00	0.00	0.00	0.00	1.67
<i>G. rotundata</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.00	0.00	0.00	0.00	0.00	1.67
Total samples	5	5	5	5	5	5	5	5	5	5	5	5	60

Table A6
Percent Abundance of Freshwater Mussels, Based on Quantitative Sampling, at Quiver
River Mile 19.7, August 1995

Species	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Total
<i>A. p. plicata</i>	82.26	83.38	77.31	52.14	72.92	50.00	77.02
<i>P. dombeyanus</i>	8.06	15.17	19.33	46.15	24.22	10.00	20.30
<i>M. nervosa</i>	0.00	0.58	0.84	0.85	2.08	20.00	1.16
<i>Q. q. quadrula</i>	3.23	0.14	0.00	0.85	0.26	0.00	0.36
<i>P. purpuratus</i>	0.00	0.14	0.00	0.00	0.26	20.00	0.29
<i>Q. pustulosa</i>	0.00	0.14	2.52	0.00	0.00	0.00	0.29
<i>O. reflexa</i>	1.61	0.29	0.00	0.00	0.00	0.00	0.22
<i>L. fragilis</i>	4.84	0.00	0.00	0.00	0.00	0.00	0.22
<i>T. verrucosa</i>	0.00	0.00	0.00	0.00	0.26	0.00	0.07
<i>F. flava</i>	0.00	0.14	0.00	0.00	0.00	0.00	0.07
Total individuals	62	692	119	117	384	10	1,384
Total species	5	8	4	4	6	4	10
Menhinik's Index	0.63	0.30	0.37	0.37	0.31	1.26	0.27
Species diversity (H')	0.69	0.52	0.65	0.78	0.71	1.22	0.67
Equitability	0.47	0.57	0.63	0.92	0.68	1.15	0.61
% Individuals < 30 mm	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Species < 30 mm	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table A7
Frequency of Occurrence of Freshwater Mussels, Based on Quantitative Sampling, at
Quiver River Mile 19.7, August 1995

Species	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Total
<i>A. p. plicata</i>	50.00	100.00	70.00	70.00	90.00	30.00	68.33
<i>P. dombeyanus</i>	40.00	100.00	40.00	80.00	90.00	10.00	60.00
<i>M. nervosa</i>	0.00	30.00	10.00	10.00	50.00	20.00	20.00
<i>Q. q. quadrula</i>	10.00	10.00	0.00	10.00	10.00	0.00	6.67
<i>P. purpuratus</i>	0.00	10.00	0.00	0.00	10.00	20.00	6.67
<i>L. fragilis</i>	30.00	0.00	0.00	0.00	0.00	0.00	5.00
<i>O. reflexa</i>	10.00	10.00	0.00	0.00	0.00	0.00	3.33
<i>Q. pustulosa</i>	0.00	10.00	10.00	0.00	0.00	0.00	3.33
<i>T. verrucosa</i>	0.00	0.00	0.00	0.00	10.00	0.00	1.67
<i>F. flava</i>	0.00	10.00	0.00	0.00	0.00	0.00	1.67
Total samples	10	10	10	10	10	10	60

Table A8
Percent Abundance of Freshwater Mussels, Based on Quantitative Sampling, at Quiver
River Mile 27.0, August 1995

Species	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Total
<i>A. p. plicata</i>	62.63	81.25	0.00	91.67	91.72	42.86	74.19
<i>P. dombeyanus</i>	29.18	13.89	0.00	8.33	1.91	9.52	17.53
<i>F. flava</i>	4.27	2.08	0.00	0.00	0.00	0.00	2.44
<i>M. nervosa</i>	0.00	0.69	0.00	0.00	3.82	14.29	1.62
<i>Q. quadrula</i>	1.42	2.08	0.00	0.00	0.00	0.00	1.14
<i>Q. pustulosa</i>	0.36	0.00	100.00	0.00	0.00	14.29	0.81
<i>P. purpuratus</i>	0.71	0.00	0.00	0.00	1.27	4.76	0.81
<i>L. fragilis</i>	0.71	0.00	0.00	0.00	0.00	4.76	0.49
<i>E. lineolata</i>	0.00	0.00	0.00	0.00	0.00	4.76	0.16
<i>E. crassidens</i>	0.36	0.00	0.00	0.00	0.00	0.00	0.16
<i>U. declivus</i>	0.00	0.00	0.00	0.00	0.64	0.00	0.16
<i>L. teres</i>	0.36	0.00	0.00	0.00	0.00	0.00	0.16
<i>T. truncata</i>	0.00	0.00	0.00	0.00	0.64	0.00	0.16
<i>O. reflexa</i>	0.00	0.00	0.00	0.00	0.00	4.76	0.16
Total individuals	281	144	1	12	157	21	616
Total species	9	5	1	2	6	9	14
Menhinik's Index	0.54	0.42	-	0.58	0.48	1.75	0.56
Species diversity	0.98	0.64	-	0.29	0.40	1.72	0.90
Evenness	0.66	0.53	-	0.60	0.38	0.84	0.49
% Individuals < 30 mm	0.36	0.00	-	0.00	0.00	0.00	0.16
% Species < 30 mm	11.11	0.00	-	0.00	0.00	0.00	7.14

Table A9**Frequency of Occurrence of Freshwater Mussels, Based on Quantitative Sampling, at Quiver River Mile 27.0, August 1995**

Species	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Total
<i>A. p. plicata</i>	90.00	80.00	0.00	60.00	100.00	30.00	60.00
<i>P. dombeyanus</i>	90.00	70.00	0.00	10.00	10.00	20.00	33.33
<i>M. nervosa</i>	0.00	10.00	0.00	0.00	40.00	30.00	13.33
<i>F. flava</i>	70.00	10.00	0.00	0.00	0.00	0.00	13.33
<i>Q. quadrula</i>	30.00	20.00	0.00	0.00	0.00	0.00	8.33
<i>P. purpuratus</i>	20.00	0.00	0.00	0.00	20.00	10.00	8.33
<i>L. fragilis</i>	20.00	0.00	0.00	0.00	0.00	10.00	5.00
<i>Q. pustulosa</i>	10.00	0.00	10.00	0.00	0.00	10.00	5.00
<i>E. lineolata</i>	0.00	0.00	0.00	0.00	0.00	10.00	1.67
<i>E. crassidens</i>	10.00	0.00	0.00	0.00	0.00	0.00	1.67
<i>U. declivus</i>	0.00	0.00	0.00	0.00	10.00	0.00	1.67
<i>L. teres</i>	10.00	0.00	0.00	0.00	0.00	0.00	1.67
<i>T. truncata</i>	0.00	0.00	0.00	0.00	10.00	0.00	1.67
<i>O. reflexa</i>	0.00	0.00	0.00	0.00	0.00	10.00	1.67
Total samples	10	10	10	10	10	10	60

Table A10**Percent Abundance of Freshwater Rivers at All Sites on the Quiver River Mile Sampled Using Quantitative Methods, August 1995**

Species	RM 6.4	RM 12.4	RM 19.7	RM 27.0	Total
<i>A. p. plicata</i>	81.48	71.71	77.02	74.19	76.11
<i>P. dombeyanus</i>	8.33	13.82	20.30	17.53	18.54
<i>M. nervosa</i>	0.93	3.95	1.16	1.62	1.46
<i>Q. pustulosa</i>	0.93	7.24	0.29	0.81	0.93
<i>F. flava</i>	0.00	0.00	0.07	2.44	0.71
<i>Q. quadrula</i>	0.00	0.00	0.36	1.14	0.53
<i>P. purpuratus</i>	0.00	0.66	0.29	0.81	0.44
<i>L. fragilis</i>	0.93	0.66	0.22	0.49	0.35
<i>P. pyramidatum</i>	4.63	0.00	0.00	0.00	0.22
<i>P. grandis</i>	0.93	1.32	0.00	0.00	0.13
<i>T. truncata</i>	0.93	0.00	0.00	0.16	0.09
<i>E. lineolata</i>	0.00	0.00	0.00	0.16	0.04
<i>A. confragosus</i>	0.93	0.00	0.00	0.00	0.04
<i>G. rotundata</i>	0.00	0.66	0.00	0.00	0.04
<i>O. reflexa</i>	0.00	0.00	0.22	0.16	0.18
<i>E. crassidens</i>	0.00	0.00	0.00	0.16	0.04
<i>L. teres</i>	0.00	0.00	0.00	0.16	0.04
<i>T. verrucosa</i>	0.00	0.00	0.07	0.00	0.04
<i>U. declivus</i>	0.00	0.00	0.00	0.16	0.04
Total individuals	108	152	1,384	616	2,260
Total species	9	8	10	14	19

Table A11**Frequency of Occurrence of Freshwater Rivers at All Sites on the Quiver River Sampled Using Qualitative Methods, August 1995**

Species	RM 6.4	RM 12.4	RM 19.7	RM 27.0	Total
<i>A. p. plicata</i>	14.00	40.00	68.33	60.00	46.96
<i>P. dombeyanus</i>	10.00	25.00	60.00	33.33	33.04
<i>M. nervosa</i>	2.00	5.00	20.00	13.33	10.43
<i>Q. pustulosa</i>	2.00	16.67	3.33	5.00	6.96
<i>P. purpuratus</i>	0.00	1.67	6.67	8.33	4.35
<i>F. flava</i>	0.00	0.00	1.67	13.33	3.91
<i>Q. quadrula</i>	0.00	0.00	6.67	8.33	3.91
<i>L. fragilis</i>	2.00	1.67	5.00	5.00	3.48
<i>P. grandis</i>	2.00	3.33	0.00	0.00	1.30
<i>O. reflexa</i>	0.00	0.00	3.33	1.67	1.30
<i>T. truncata</i>	2.00	0.00	0.00	1.67	0.87
<i>P. pyramidatum</i>	2.00	0.00	0.00	0.00	0.43
<i>E. crassidens</i>	0.00	0.00	0.00	1.67	0.43
<i>L. teres</i>	0.00	0.00	0.00	1.67	0.43
<i>G. rotundata</i>	0.00	1.67	0.00	0.00	0.43
<i>A. confragosus</i>	2.00	0.00	0.00	0.00	0.43
<i>E. lineolata</i>	0.00	0.00	0.00	1.67	0.43
<i>T. verrucosa</i>	0.00	0.00	1.67	0.00	0.43
<i>U. declivus</i>	0.00	0.00	0.00	1.67	0.43
Total sites	5	12	6	6	29
Total quadrats	50	60	60	60	230

Appendix B

Results of Qualitative and Quantitative Sampling for Freshwater Mussels in Bogue Phalia, Mississippi, 1995

Table B1 Percent Species Abundance of Freshwater Bivalves Using Qualitative Methods at 11 Sites on Bogue Phalia, Mississippi, 15 August 1995													
Species	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Total	
	RM 33.7	RM 25.6	RM 27.4	RM 28.2	RM 32.2	RM 35.8	RM 39.8	RM 47.5	RM 59.5	RM 60.8	RM 66.9	RM 66.9	Total
<i>A. p. plicata</i>	33.33	22.22	0.00	81.63	40.00	0.00	0.00	76.48	90.01	85.30	91.07	78.14	78.14
<i>P. dombeyanus</i>	33.33	66.66	0.00	14.29	0.00	0.00	0.00	0.00	0.00	0.00	3.57	10.70	10.70
<i>P. grandis</i>	16.67	0.00	0.00	0.00	0.00	0.00	0.00	11.76	0.00	8.82	0.00	2.79	2.79
<i>Q. quadrula</i>	0.00	5.56	0.00	0.00	20.00	0.00	0.00	5.88	0.00	0.00	3.57	2.33	2.33
<i>P. purpuratus</i>	0.00	5.56	0.00	2.04	20.00	0.00	0.00	5.88	0.00	0.00	0.00	1.86	1.86
<i>L. fragilis</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.33	0.00	1.79	0.93	0.93
<i>L. teres</i>	0.00	0.00	0.00	2.04	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.93	0.93
<i>L. subrostrata</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.88	0.00	0.93	0.93
<i>Q. nodulata</i>	16.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.33	0.00	0.00	0.93	0.93
<i>P. imbecillis</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.33	0.00	0.00	0.46	0.46
Total individuals	6	18	0	49	5	0	0	17	30	34	56	215	215
Total species	4	4	0	4	4	0	0	4	4	3	4	10	10
Total collection time, min	20	20	20	20	20	20	20	20	20	20	20	220	220
Mussels/min	0.30	0.90	0.00	2.45	0.25	0.00	0.00	0.85	1.50	1.70	2.80	0.98	0.98

Table B2
Quantitative Data on Freshwater Mussels From Three Sites on Bogue Phalia River Mile 41.72, Mississippi, October 1995

Species	Site 1		Site 2		Site 3		Total	
	Abun	Freq	Abun	Freq	Abun	Freq	Abun	Freq
<i>A. p. plicata</i>	0.00	0.00	75.00	20.00	50.00	10.00	70.00	10.00
<i>Q. quadrula</i>	0.00	0.00	12.50	10.00	0.00	0.00	10.00	3.33
<i>P. purpuratus</i>	0.00	0.00	0.00	0.00	50.00	10.00	10.00	3.33
<i>A. confragosus</i>	0.00	0.00	12.50	10.00	0.00	0.00	10.00	3.33
Total individuals	0		8		2		10	
Total samples		10		10		10		30
% Individuals < 30 mm							0.00	
% Species < 30 mm							0.00	
Menhinik's Index							1.26	
Species diversity (H')							0.94	
Equitability							0.73	

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13. ABSTRACT (Maximum 200 words) A survey to assess community characteristics, density, population demography of dominant species, and the presence of rare or endangered species of mussels (Family: Unionidae) was conducted in selected reaches of the Quiver River and Bogue Phalia, Mississippi, in 1994 and 1995 for the U.S. Army Engineer District, Vicksburg. Results are being used to assess the economic value of mussels in the project area and to determine the environmental effects of proposed maintenance dredging. The project area included a section of the Quiver River between its confluence with the Big Sunflower River immediately north of Highway 82 in Sunflower County to the Leflore-Tallahatchie county line. In the Bogue Phalia, the study area consisted of a reach between Highway 82 and Rosedale, west-central Bolivar County. Twenty-two species of native freshwater mussels were collected in the Quiver River; 26 sites were sampled using qualitative methods, and a total of 2,238 mussels were collected. The dominant mussel was <i>Amblema p. plicata</i> , which comprised over 67 percent of the mussel fauna. <i>Plectomerus dombeyanus</i> comprised 20 percent of the mussels. Overall species diversity (0.67 to 0.90) was low, mainly because of the dominance of <i>A. p. plicata</i> . Evidence of recent recruitment was low; approximately 7 percent of the species and 0.15 percent of the individuals collected were less than 30 mm total shell length. Overall mean density ranged from less than 8.6 individuals/square meter at River Mile (RM) 6.4 to 92.3 individuals/square meter at RM 19.7. (Continued)					
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Qualitative collections for mussels were made at 11 sites on Bogue Phalia. This river exhibited low density (overall mean was 1.3 individuals/square meter) with low species richness (only 10 species were found). At four sites on Bogue Phalia, total mean density ranged from 0.0 to 3.2 individuals/square meter; the overall mean was 1.33 individuals/square meter. The fauna was dominated by *A. p. plicata*, which comprised 70 percent of the collection. If mussels sell at \$1 per pound from the project area, the total value would be approximately \$910,000 in the Quiver River and \$5,000 in Bogue Phalia.

Maintenance dredging and commercial shell harvest could negatively affect common and uncommon species in both rivers. The lack of recent recruitment, dominance of a single species, and low species richness make these mussels vulnerable. Commercial harvest should be carefully regulated and monitored, and selected reaches should be set aside as sanctuaries. The long-term survival of this resource could be ensured by regular monitoring and careful adherence to a well-designed dredging and commercial harvest plan.